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Fire Endurance Test of a Roof/Ceiling Construction of Paper Honeycomb and Gypsum Board

B. C. Son

Center for Building Technology
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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by
B. C. Son
Building Fires and Safety Section
Center for Building Technology

ABSTRACT

In a program of evaluation of various housing systems proposed under Operation BREAKTHROUGH, a fire endurance test was performed at the National Bureau of Standards on a roof/ceiling assembly consisting of a paper honeycomb structural core surfaced on both sides with glass-fabric impregnated with polyester resin and outer layers of gypsum board.

The test method was generally in accordance with the requirements of ASTM E 119, Fire Tests of Building Construction and Materials, for loadbearing roof assemblies. The applied load was 15.9 psf and the test results are valid only for roof/ceilings of similar construction loaded at or below the stress level developed by this loading.

Under the loading of 15.9 psf on a 13 ft. 5 in. span, which produced a stress equivalent to the application of 20 psf on a 12 ft. span, failure occurred by flame-through of the roof/ceiling assembly at 37 min. 13 sec.

Key Words: Fire endurance; fire test; flame-through failure, structural panel; glass-fabric reinforced plastic; housing systems; Operation BREAKTHROUGH; paper honeycomb; roof/ceiling assembly; structural panel

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1.0 INTRODUCTION

A sandwich panel roof/ceiling assembly designed for single family attached housing was submitted for a fire endurance test at the National Bureau of Standards under the Operation BREAKTHROUGH program conducted for the Department of Housing and Urban Development. The test was run generally in accordance with the requirements of the Standard Methods of Fire Tests of Building Construction and Materials, ASTM E 119[1/].

The assembly panels consisted of paper honeycomb cores surfaced on both sides with glass-fabric impregnated with polyester resin and gypsum board covers. The exterior (top) side of the panels had an additional weather-resistant surfacing. The panels were unframed except for closeout pieces at the edges.

2.0 DESCRIPTION OF TEST SPECIMEN

The roof/ceiling assembly, as shown in figure 1, consisted of two panels of equal size, each 13 ft. 5 in. by 8 ft. 11 in., butted on the long side to fit in the NBS floor test furnace.

The panels consisted of 6 in. thick flame-retardant treated paper honeycomb cores with woven glass fiber roving and polyester resin facings bonded to both sides of the core. Type X gypsum board, 5/8 in. thick, was applied to the resin facings with a polyester adhesive reinforced with one percent asbestos fiber. The joints in the boards on the two sides of a panel were staggered. The weather-resistant coating applied to the gypsum board on the exterior side of the panels consisted of a resin with

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[1/] Standard Methods of Fire Tests of Building Construction and Materials, American Society for Testing and Materials Designation E 119-71, available at 1916 Race Street, Philadelphia, Pa. 19103.

chopped glass fiber and sand. The joints between the gypsum boards on the surface of the panels were taped and filled with plaster joint compound.

The honeycomb core was stopped 3 in. from the long edges of each panel to allow for finishing with four layers of 3/4 in. plywood, laminated to form a 3 in. by 6 in. section. Although the panels were ostensibly unframed, these plywood closures in effect provided 3 in. by 6 in. beams at the extreme ends of the test specimen and a 6 in. by 6 in. beam at its center. The exposed side of the joint at the specimen center, between the panels, was covered with a 5 in. wide strip of 5/8 in. gypsum board.

With the panels installed the clearance between the panel edges and the furnace walls was 1/2 to 1 in. These spaces were closed by the furnace flanges which supported the test structure on its perimeter and by mineral wool stuffing.

3.0 TEST METHOD AND INSTRUMENTATION

The roof/ceiling assembly, tested in the NBS floor furnace, was exposed on its underside to a fire controlled to give an average temperature in the furnace in accordance with the time-temperature curve of the ASTM E 119 standard. Figure 2 is a section of the floor-test furnace with typical specimen in place.

The temperature within the furnace was determined from the readings of 12 protected thermocouples symmetrical distributed in the chamber.

To determine the temperatures on the unexposed surface of the specimen, nine Chromel-Alumel (type K) thermocouples were located in a symmetrical pattern over the two panels, four away from the joint

on each panel and one at the center over the joint (locations shown in figure 1). Each thermocouple was covered with a standard asbestos pad (6 by 6 by 0.4 in.) as specified in the ASTM E 119 standard. Additionally, three thermocouples were placed in the core within each panel. Temperature readings indicated by all the thermocouples, including those in the furnace, were recorded at 1-minute intervals on a data logger and later processed and plotted by computer.

Vertical deflections of the panels during the test were measured at three points on the longitudinal center line, at the midpoint over the joint and at either quarter point. Indication of movement was by pointers on wires attached to the three check points. The wires, held taut by weights, passed over pulleys which in turn were connected to linear deflection potentiometers.

Conventional roof design live loading on a structure for which the panels under test are intended was taken as 20 psf. The panels are normally manufactured in 12 ft. widths. The 13 ft. 5 in. wide specimens of this test were made specially to conform to the size of the NBS floor furnace. A load of 15.9 psf was applied to the test specimen to provide a bending moment in the wider panels equivalent to that produced by 20 psf loading on a 12 ft. span. Applied symmetrically at 36 points by means of 6 by 24 in. channels, the load was approximately uniform over the entire surface. Although the load was applied 24 hours before the start of the fire endurance test no significant creep deflection was observed.

4.0 TEST EVALUATION

The fire endurance of a roof/ceiling structure according to ASTM E 119 is the time required to reach the first occurrence of the following criteria of failure:

1. Inability to sustain the applied load.
2. Passage of flame or gas, through the structure to the unexposed surface, hot enough to ignite cotton waste.
3. A temperature rise of 250°F (139°C) average, or 325°F (181°C) at one point above the initial temperature on the unexposed surface.

5.0 RESULTS OF TEST

Failure occurred at an observed time of 37 min. 50 sec. by flame-through at the unexposed surface through a joint in the gypsum boards of one of the panels. A local load failure occurred about 10 sec. later at the site of the flame penetration.

Since, as indicated by figure 2, the average temperature in the furnace (figure 2) was slightly below that provided by the standard time-temperature curve, the time to failure was corrected to 37 min. 13 sec., by the correction formula in ASTM E 119.

At the time of failure, the average temperature of the unexposed surface was 136°F (58°C), the maximum at one point 182°F(83°C), indicating that the initial flame-through did not occur in the immediate vicinity of any of the thermocouples. Temperatures at the six thermocouples inside the panel show suddenly accelerated rises at times corresponding to the falling of the ceiling gypsum boards (30 min.).

Time-temperature curves for the thermocouples on the unexposed surface are shown in figure 4; those in the paper core, in figure 5. The flame-through failure and the inability to sustain the load at the failure point are illustrated in figure 6.

The rate of measured deflection on the panels was slow until about 30 min. of the test and after that time the rate of the deflection increased slightly at the two quarter points. There was no significant deflection at the center point at any time. Figure 7 shows the deflection at the two quarter points.

A log of test observations is given in the Appendix.

6.0 DISCUSSION OF RESULTS

The local distintegration of the gypsum board under one of the loading members probably accelerated by the burnout of the supporting core, provided the opening for the initial breakthrough of flame to cause failure. Effects of the fire exposure on the underside of the specimen can be seen in figures 8 and 9.

Absence of deflection at the center of the roof/ceiling panel can be attributed to the support provided by the closeout pieces at the edges of the two panels making up the assembly. These laminated plywood beams, with load carrying capacity far in excess of the total applied to the structure, were not only protected from the fire by the gypsum board ceiling beneath, but in themselves over the time period of this test, would maintain a considerable capacity to sustain load even if fully exposed to the fire. It should be noted that in actual construction the closeout pieces, even if comparable in size and material, would probably not be supplied in the close spacing used in the test specimen.

The applied load of 15.9 psf in this test, corresponded to a 20 psf live load on a 12 ft. span. Therefore, the results of this test are applicable only to similar roof/ceiling structures with spans and loads developing a bending moment not exceeding that developed in the structure tested.

The flame retardant treatment said to have been applied to the paper honeycomb core apparently did little or nothing to prevent its destruction when exposed to fire. After test, the paper honeycomb core continued to smolder for several hours with occasional eruption into open flaming. Figure 10 shows flaming of the core material two hours after application of a water spray from a fog nozzle at the conclusion of the fire exposure.

TABLE I

Log of Test Observations

TIME min:sec	OBSERVATIONS
0:00	Start of test.
2:00	Blue flame over the exposed surface.
3:00	Flame subsided.
4:00	Blue flame again spreading over the exposed surface.
4:20	Flame not apparent. Much smoke coming through the unexposed surface.
24:00	Flaming at a gypsum joint near south* quarter point on exposed surface (honeycomb core appears to be burning).
28:00	Large flaming at the middle of the south panel on exposed surface (opening up of the gypsum joints).
30:00	Bottom layer of gypsum board on south panel has started to fall into the furnace.
30:50	Furnace filling with smoke and flame. Deflection of 1-in. at the south quarter point was observed on the recorder.
35:00	A gypsum joint near and to the south of the center on the unexposed surface started to open and the gypsum board under a nearby loading point was being crushed.
37:50	Flame-through occurring at the point where the gypsum board was failing under a loading point (see Figure 6).
38:00	Pieces of the upper layer of gypsum board at this loading point falling into the furnace (a local load failure).
39:00	Gas off, end of test.

* To identify the location of an occurrence, the two ends of the assembly are differentiated according to their orientation.

APPENDIX I

SI Conversion Units

In view of present accepted practice in this country in this technological area, common US units of measurement have been used throughout this paper. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measurements which gave official status to the metric SI system of units in 1960, we assist readings interested in making use of the coherent system of SI units by giving conversion factors applicable to US units used in this paper.

Length

1 in = 0.0254 meter
1 ft = 0.3048 meter

Mass

1 pound = 0.45 kilograms

Force

1 kip = 4448 newton

Stress

1 psf = 47.88 newton/meters^2

Temperature

Temperature in °F = 9/5 (Temperature in °C) + 32°F

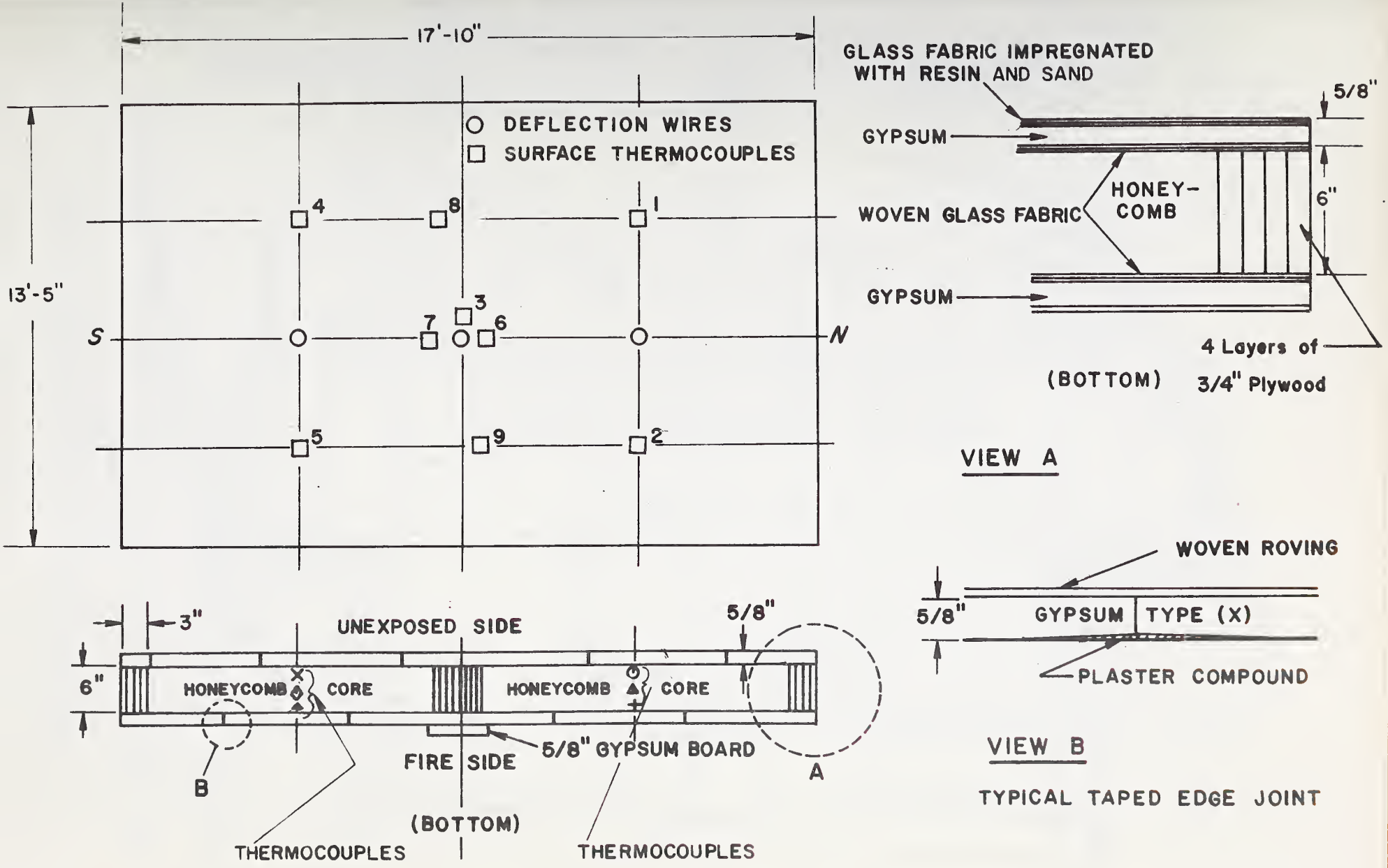

Figure1. Details of construction and locations of thermocouples for roof-ceiling specimen

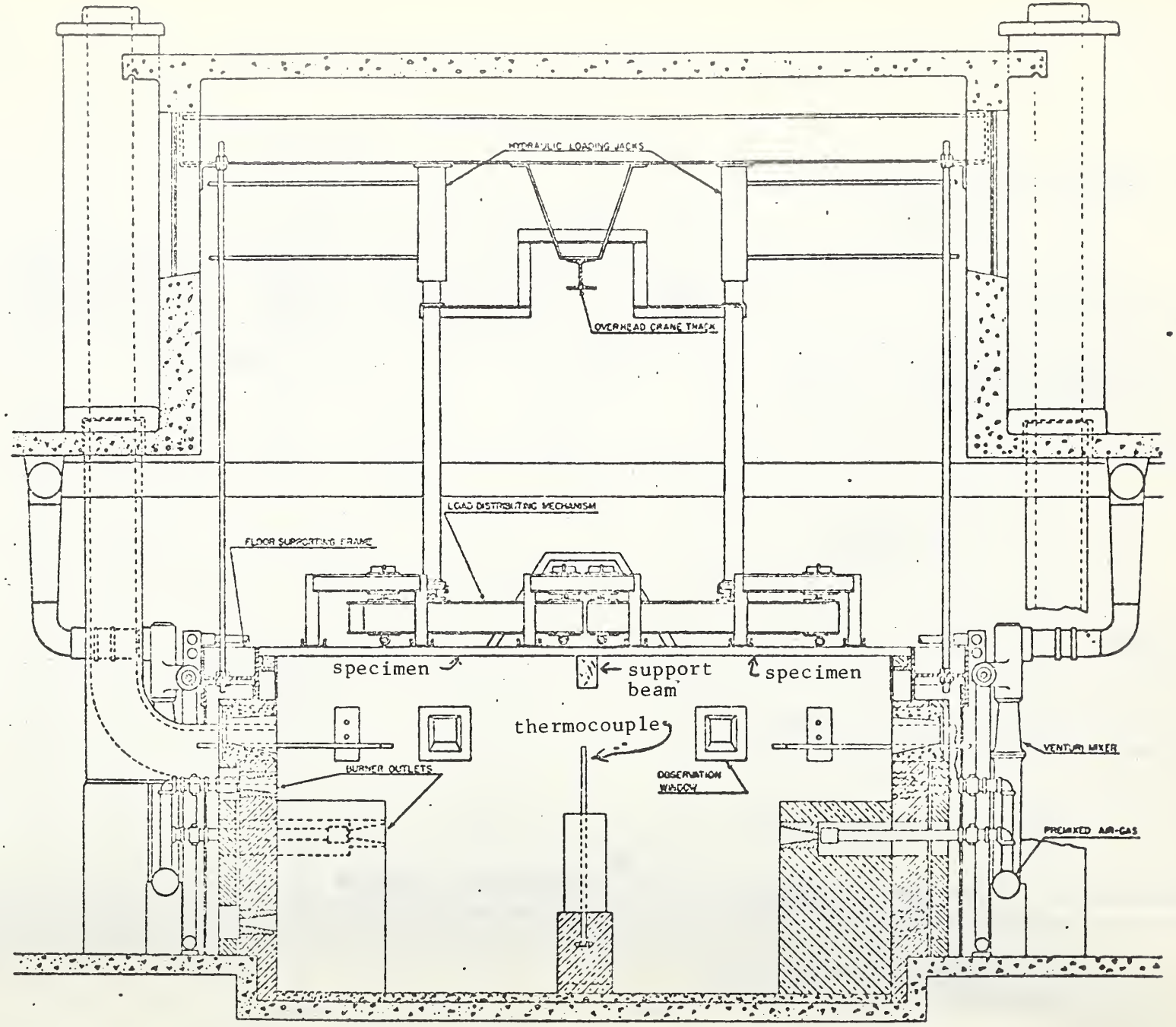

FIGURE 2. Section of the large floor-test furnace at NBS.

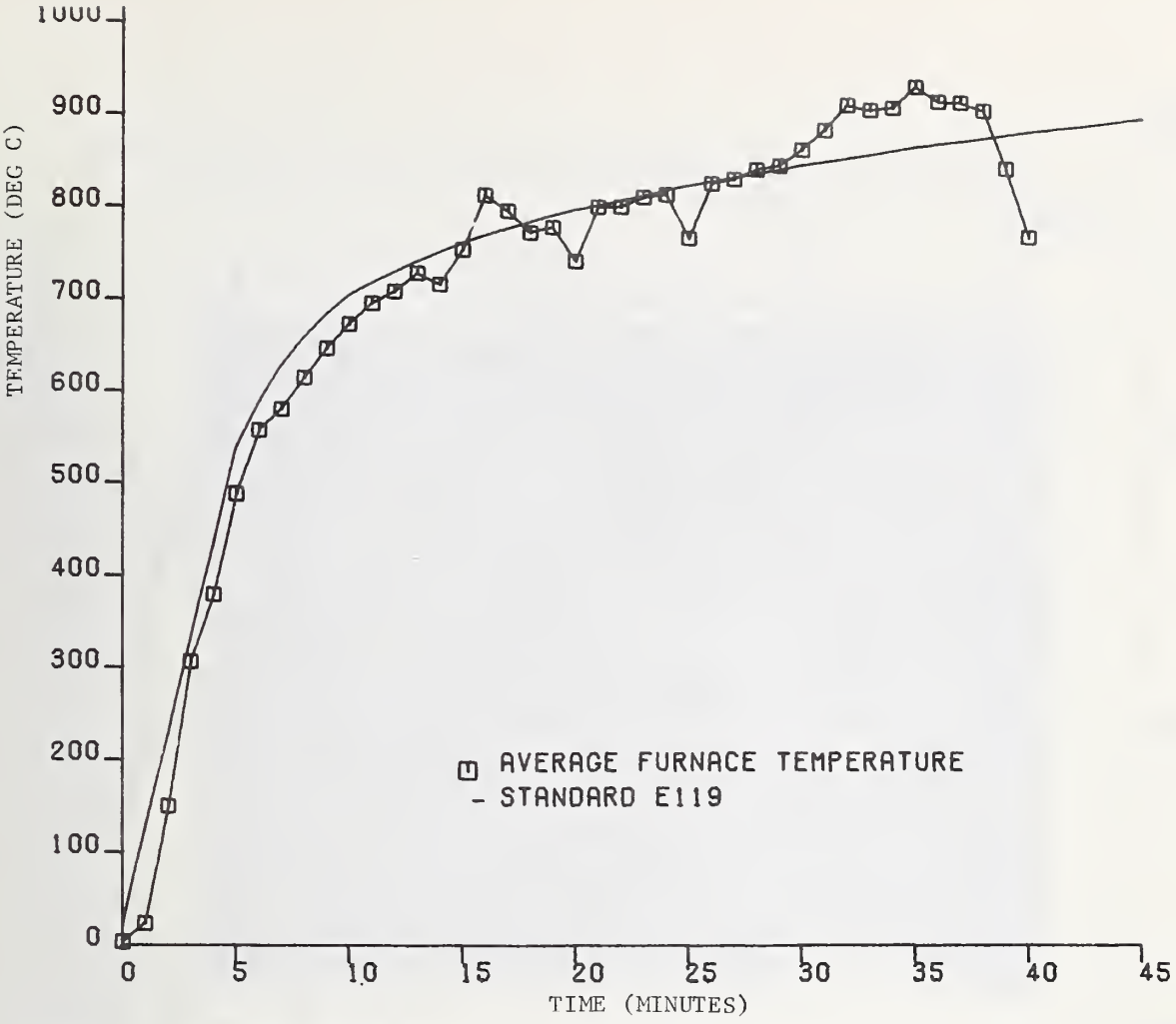

Figure 3. AVERAGE FURNACE TEMPERATURE FOR TEST 482 COMPARED WITH STANDARD E119.

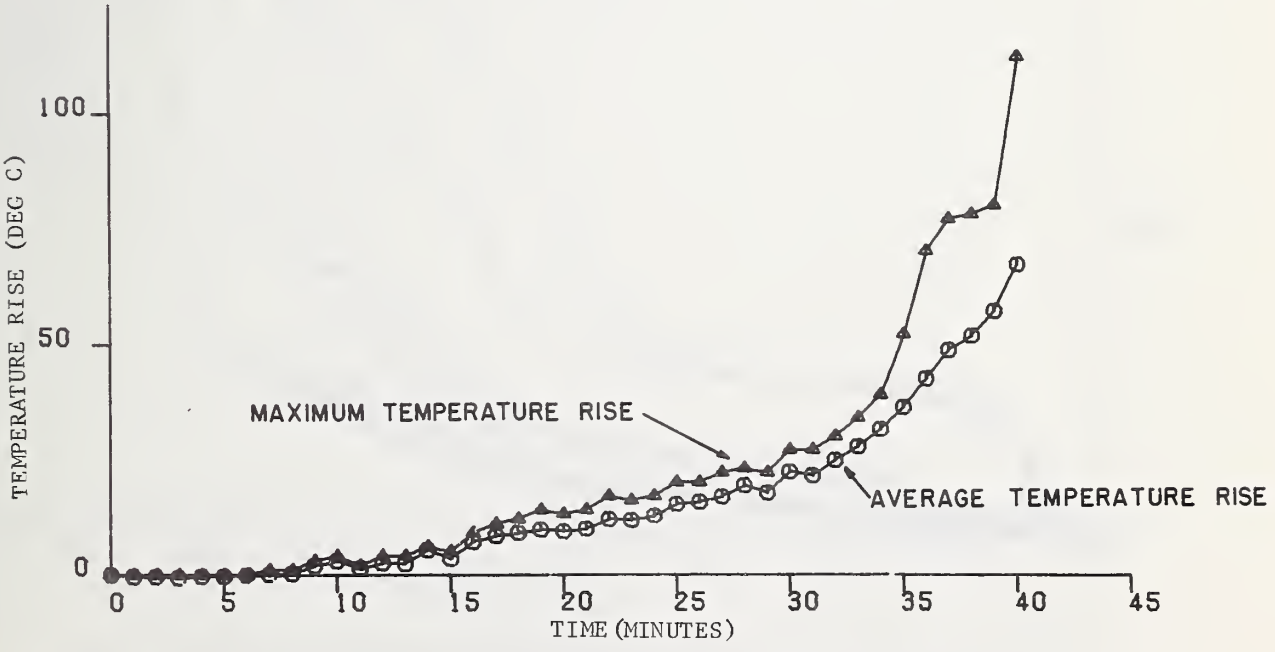

Figure 4. MAXIMUM AND AVERAGE SURFACE TEMPERATURE RISE FOR TEST 482

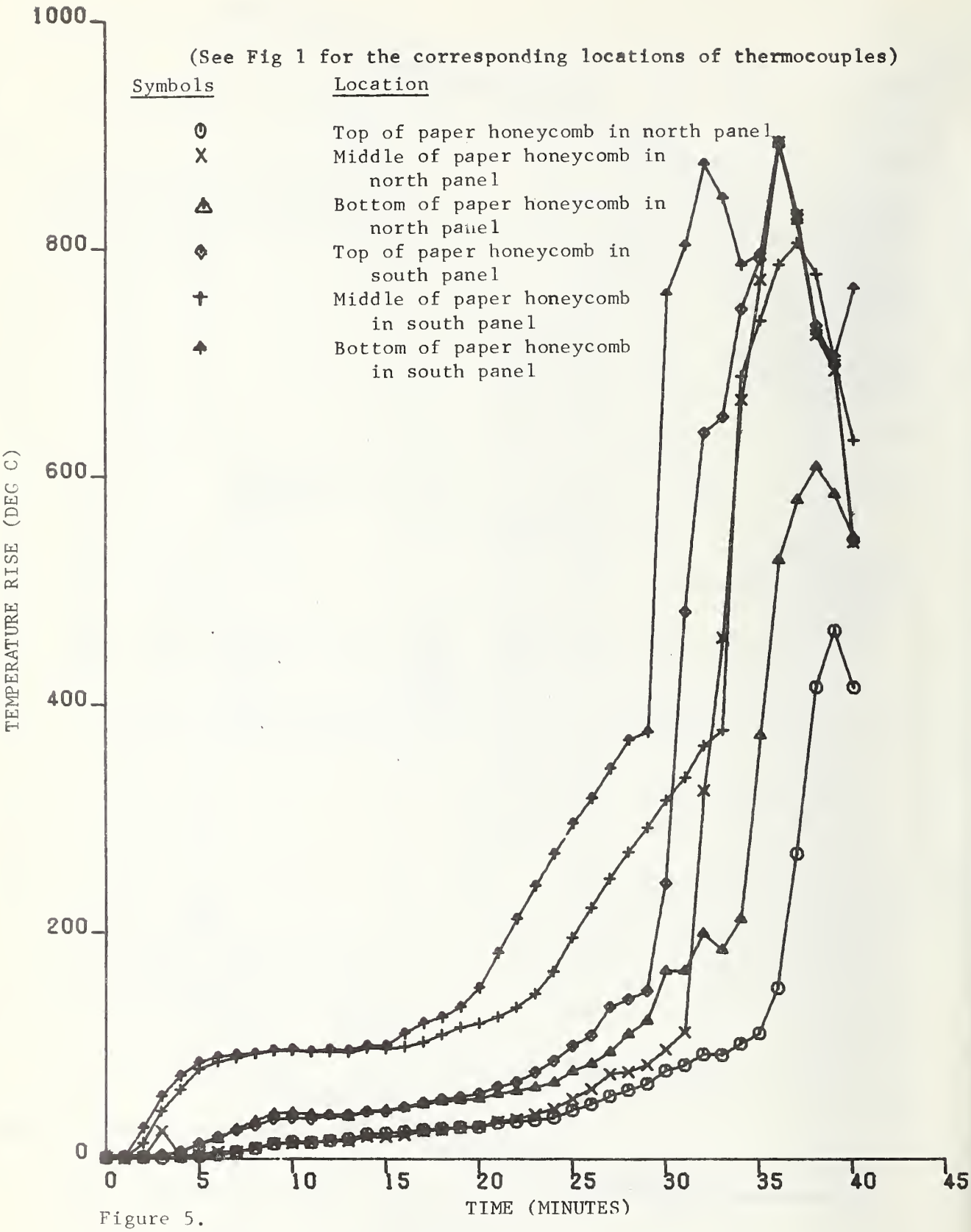

Figure 5.

TEMPERATURE RISES AT SIX THERMOCOUPLES WITHIN ROOF-CEILING ASSEMBLY.

Figure 6. Flame through near center, with local load failure.

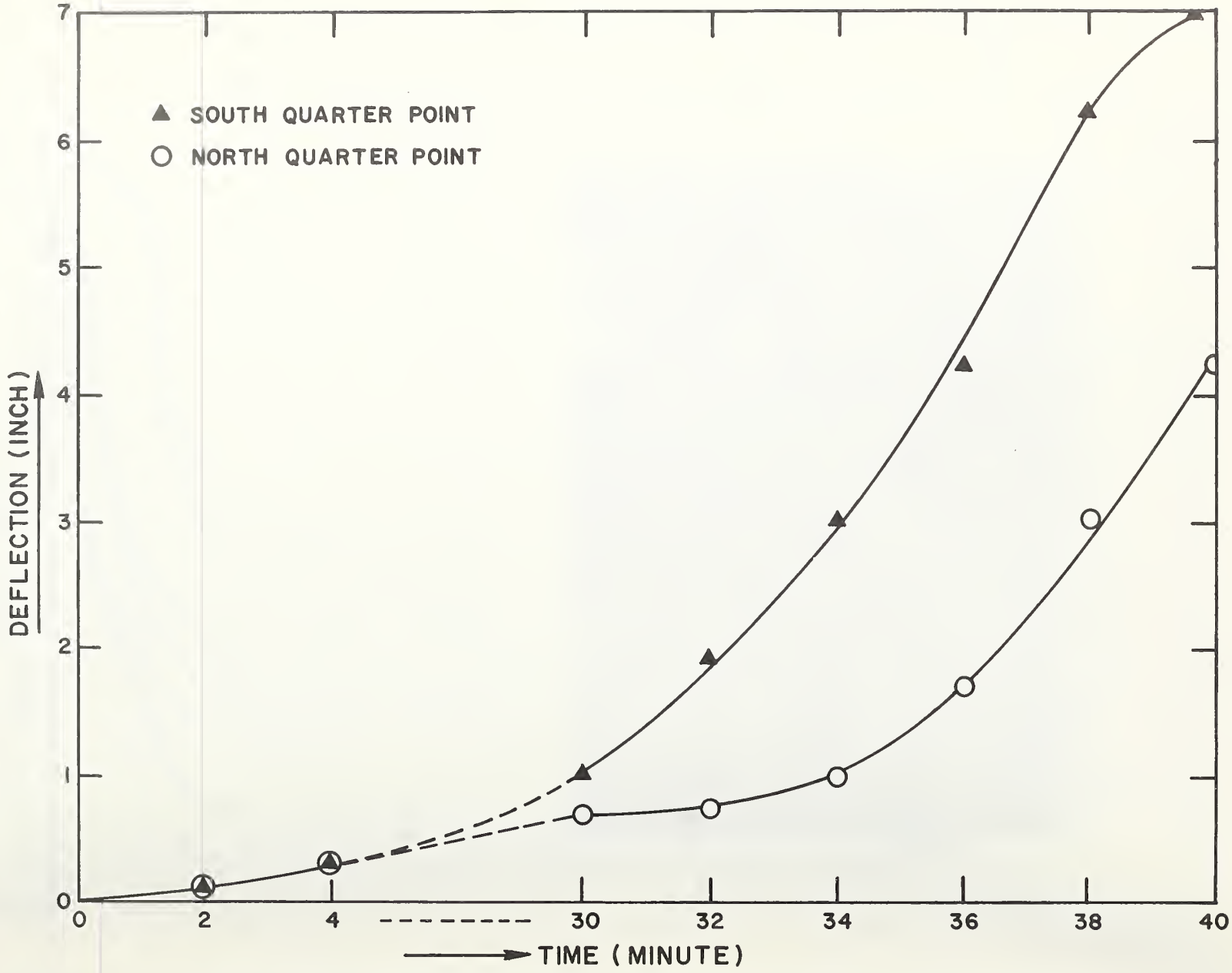

Figure 7. Deflections at north and south quarter point vs time.

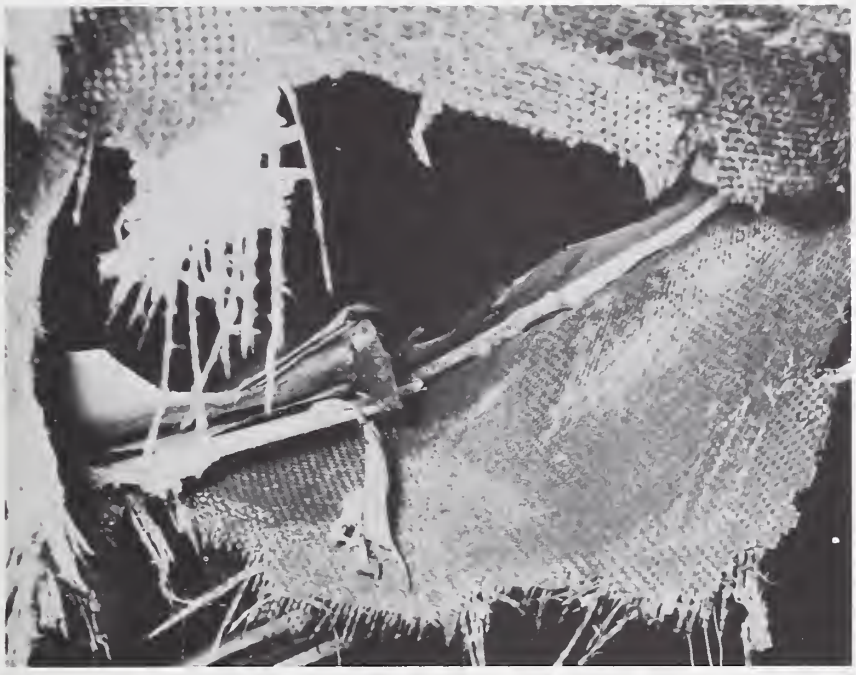

Figure 8 The close up of the edge of the hole.
(Woven glass roving with resin, paper, gypsum board)

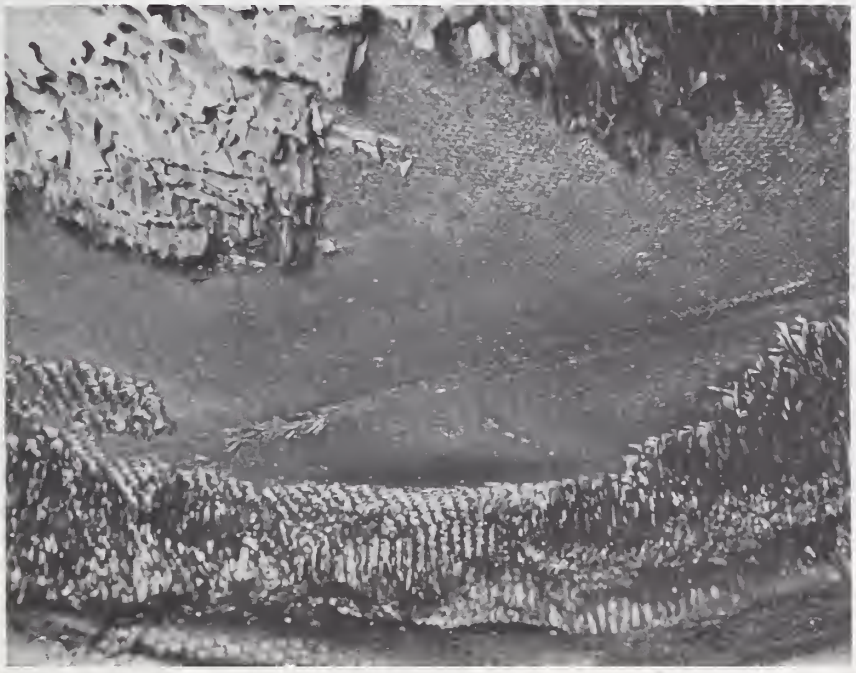

Figure 9 The deterioration of the underside of the specimen.

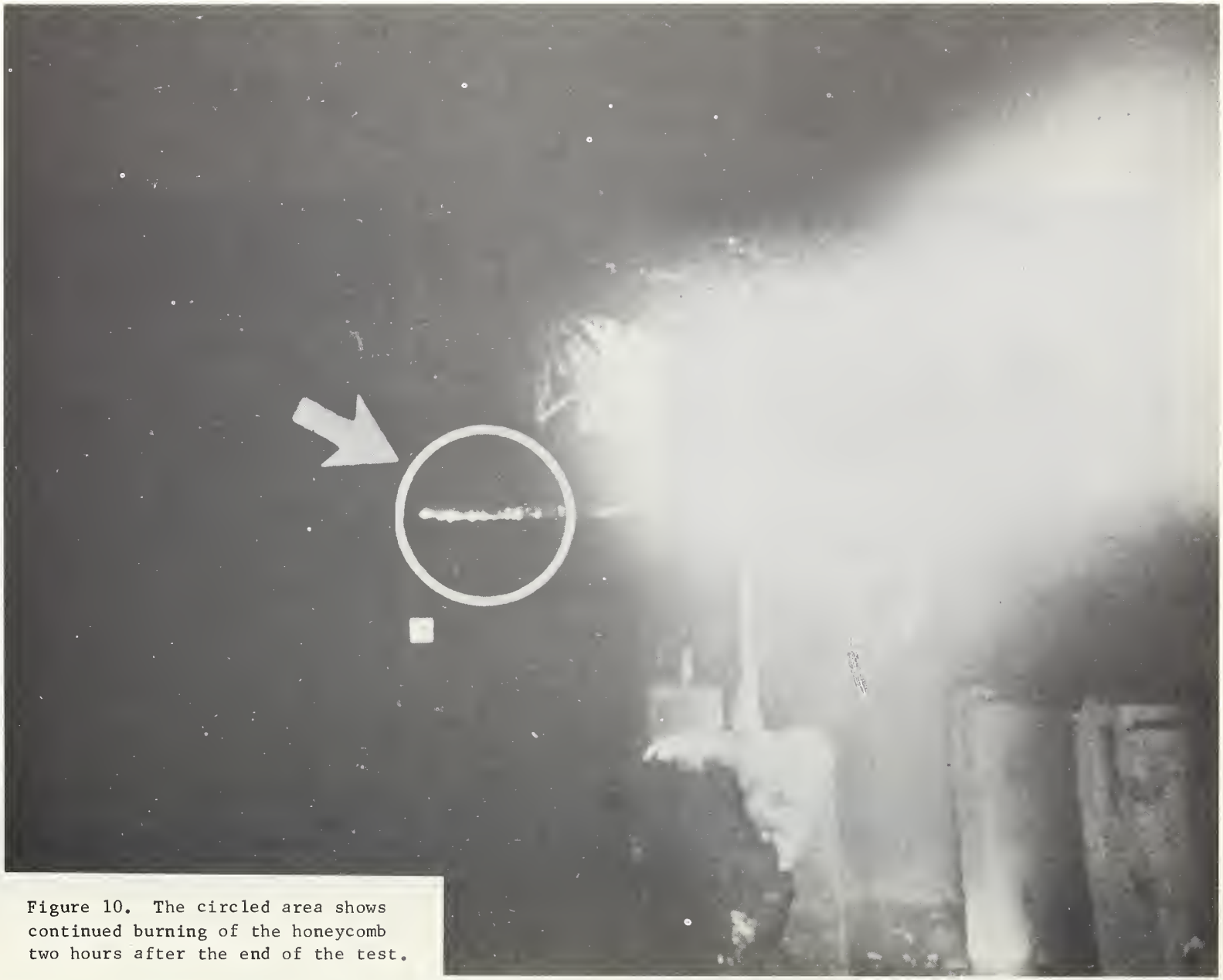

Figure 10. The circled area shows continued burning of the honeycomb two hours after the end of the test.

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

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17. KEY WORDS (Alphabetical order, separated by semicolons) Fire endurance; fire test; flame-through failure, structural panel; glass-fabric reinforced plastic; housing systems; Operation BREAKTHROUGH; paper honeycomb; roof/ceiling assembly; structural panel

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